Energy, Mines and Resources Canada

Hon. Marcel Masse, Minister

Énergie, Mines et Ressources Canada

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Canada

DESIGN, BUILD AND EVALUATE THE FORINTEK MOISTURE SENSOR FOR MEASURING ON-LINE MOISTURE CONTENT (MC) IN UNSEASONED LUMBER AND HOG FUEL

RENEWABLE ENERGY BRANCH

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PREPARED BY:
Sita R. Warren, Gary Troughton and Mark Ward
Forintek Canada Corp.
Western Region
6620 N.W. Marine Drive
Vancouver, B.C.
V6T 1X2
(Telephone No: 604-224-3221)

SCIENTIFIC AUTHORITY:
Ms. Cecile Granger
Energy, Mines and Resources Canada
580 Booth St. Ottawa
Ontario K1A 0E4

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PREFACE

The new Forintek moisture sensor is a non-contact method for measuring moisture contents of unseasoned lumber, veneer, hog-fuel and other wood products. The principle is based on applying a known quantity of heat energy to a wood surface and measuring the heat use. Many methods are available for the determination of moisture contents but they are not attractive because they are inaccurate above the fiber saturation point (above 30 percent) and they work on the contact method.

The Forintek moisture sensor offers an accurate on-line system for measuring the moisture content of unseasoned lumber, veneer, and hog fuel. Commercial plant trials were conducted at Weldwood of Canada (Williams Lake) to sort unseasoned beetle-killed lumber.

The results of the commercial trials showed that if the sensor is used on the green grain for sorting lumber then the economic saving based on grade outturn and recovery is $8.50 per 1,000 bd. ft. This figure is significant since the energy savings were not taken into account.

Another result that is of interest to the pulp and paper companies is that the sensor can be used for policing the fossil fuel consumption for proper control of boilers. The sensor was used to measure the moisture contents of hog fuel from the interior and the coast of British Columbia to ascertain the daily as well as the monthly fluctuations. The outcome of these experiments has generated enough interest at the MacMillan Bloedel plant that they have offered their support in installing a sensor to measure the moisture content of their mill residue. This plant generates 60 percent of their energy from hog fuel and their savings could be up to one million dollars per annum.

ABSTRACT

A new plant prototype moisture sensor was designed, built and tested for: a) sorting unseasoned lumber on a commercial scale; b) a laboratory model was designed, built and tested to measure the moisture content of hog fuel to ascertain the daily, weekly and monthly fluctuations for boiler operations in the pulp plants. The principle of the new moisture sensor is based on the relationship between moisture content and surface temperature rise after the material has received a known quantity of heat energy.

A preliminary mill trial for sorting lumber was conducted at the Weldwood plant (Williams Lake) on November 14 and 15, 1986, to establish the following: a) the economics of sorting; b) whether the mill should proceed with a commercial run. The results of the preliminary trial based on economics were sufficiently promising to warrant a large commercial trial; this was conducted in March, 1987. The savings based on grade outturn and recovery on 100,000,000 bd.ft. are over one million dollars.

The daily, weekly and monthly fluctuations of the hog fuel indicated that the moisture sensor could be used in pulp mills to monitor boiler operations.

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EXECUTIVE SUMMARY

The two major objectives in the present study were the following: 1) to design, build and evaluate a new plant prototype moisture sensor for sorting unseasoned lumber on a commercial scale and to determine the economic benefits to the forest products industry; and 2) to design, build and evaluate a laboratory model moisture sensor for measuring moisture content in hog fuel to determine the weekly and monthly moisture content change for use in boiler operation in pulp and paper plants. The principle of the new moisture sensor is based on applying a known quantity of heat energy to a wood surface and measuring the heat rise.

Various methods including electrical, microwave and nuclear radiation, have been used to measure moisture content in unseasoned wood materials. In general, however, these methods are limited in accuracy since they require a knowledge of the bulk density of the material.

To address objective 1, a new plant prototype moisture sensor for lumber was designed and built at the Western Laboratory, Forintek Canada Corp. This sensor was then installed on the green chain near the J-bar at the Weldwood of Canada mill site in Williams Lake. The prototype sensor contained two 5,000 watt infrared heaters to preheat the lumber surface and three Telatemp infrared 44-1MAR heat sensors triggered by three photocells to measure temperature rise. The Forintek moisture sensor was interfaced through an IBM-PC microcomputer to the sorting computer in order to sort the lumber. The line speed was 90 ft./min.

The results of preliminary mill trials were sufficiently promising to warrant a full scale commercial trial. About 0.5 million board feet of unseasoned spruce-pine-fir (SPF) lumber was sorted into a dry and wet sort. The moisture content cutoff point for sorting was 35 percent. This lumber, along with a control, was dried for different schedules in a kiln. The increase in percent recovery of the wet and dry sorts over the control was 3.45 percent. Based on the percent recovery and outturn evaluation, the economic benefits were $8.5 per 1,000 bd.ft. Further, the drying time was reduced by about 22 percent, resulting in greater kiln capacity and energy savings due to shorter kiln schedules. Thus for a forest products plant producing 100,000,000 bd.ft. of lumber per year, savings of over one million dollars could be realized.

The accurate on-line measurement of hog fuel moisture content is extremely important for the efficient operation of a boiler in the pulp and paper industry. The hog fuel is generally fed to the boiler by a conveyor belt system, thus the moisture content must be measured rapidly to permit appropriate furnace adjustments. Changes in the hog fuel moisture content are compensated by the use of supplementary fossil fuels. Poor control of the boiler leads to inefficient combustion and unacceptable smoke emission.

To address objective 2, a moisture sensor was built at the Western Laboratory, Forintek Canada Corp., to measure moisture content in hog fuel. This sensor contained one 2,200 watt heater to preheat the hog fuel and two Telatemp infrared 44-1MAR heat sensors triggered by two photocells to measure temperature rise. Moisture content measurements made on hog fuel collected both from a B.C. coastal and interior site each showed a large day-to-day fluctuation in moisture content. This finding indicates the importance of being able to control fossil fuel addition to the boiler in a pulp and paper plant by rapidly and accurately measuring the hog fuel moisture content. By installing the new Forintek moisture sensor to control the addition of bunker fuel to the boiler, the savings calculated for the MacMillan Bloedel pulp and paper Harmac plant are estimated to be one million dollars annually.

The results in this report indicate that the new Forintek moisture sensor has excellent potential for rapid on-line measurement of moisture content in both unseasoned lumber and hog fuel and demonstrate that this moisture sensor can be effectively used for process control. It is recommended that the new moisture sensor undergo trials at a pulp and paper plant to control the boiler operation by measuring hog fuel moisture content and controlling the fossil fuel addition.

RÉSUMÉ

Les objectifs principaux de la présente étude étaient : 1) de concevoir, de construire et d'évaluer un prototype de détecteur d'humidité destiné aux usines, pour le triage du bois non séché à l'échelle commerciale et de déterminer les avantages économiques du détecteur, pour l'industrie forestière; et 2) de concevoir, de construire et d'évaluer un détecteur d'humidité pour mesurer en laboratoire la variation de la teneur en humidité, au cours d'une période d'une semaine ou d'un mois, des résidus de bois destinés à alimenter les chaudières dans les usines de pâtes et papiers. Le principe du nouveau détecteur d'humidité est d'appliquer une quantité déterminée d'énergie thermique à une surface de bois et de mesurer l'augmentation de la chaleur.

Différentes méthodes, dont l'utilisation de l'électricité, de micro-ondes et de radiations nucléaires, ont été employées pour mesurer la teneur en humidité du bois non séché. En général, cependant, l'exactitude de ces méthodes est limitée, car elles nécessitent la connaissance de la masse volumique du matériel.

Relativement au premier objectif, un nouveau prototype de détecteur d'humidité du bois, pour usage en usine, a été conçu et construit au laboratoire de l'Ouest de la société Forintek Canada. L'appareil a ensuite été fixé au-dessus du bois vert, près du fer en J, à l'usine Weldwood of Canada de Williams Lake. Le prototype contenait deux radiateurs à infrarouge d'une puissance de 5 000 watts pour chauffer la surface du bois et trois détecteurs de chaleur infrarouge Telatemp de modèle 44-1MAR actionnés par trois cellules photo-électriques pour mesurer l'augmentation de la température. Le détecteur d'humidité Forintek a été couplé à l'ordinateur de triage, par l'intermédiaire d'un micro-ordinateur IBM-PC, afin d'effectuer le tri du bois. Le bois a été acheminé à 90 pi/min.

Les résultats des essais préliminaires à l'usine étaient assez prometteurs pour justifier un essai à l'échelle commerciale. Un

demi-million de pieds de planche d'épinette, de pin et de sapin ont été répartis en bois humide et en bois sec. Pour le triage, le point d'arrêt de la teneur en humidité était de 35 p. 100. Ce bois, ainsi qu'un ensemble témoin de planches, a été séché pendant différentes périodes dans un séchoir. L'augmentation du pourcentage de récupération du bois humide et sec, par rapport à l'ensemble témoin, a été de 3,45 p. 100. D'après le pourcentage de récupération et l'évaluation du rendement, les avantages économiques s'élevaient à 8,5 $ par 1 000 pieds de planche. En outre, la durée de séchage a été réduite d'environ 22 p. 100, entraînant une plus grande capacité de séchage et des économies d'énergie. Ainsi, une usine de produits forestiers traitant 100 millions de pieds de planche par année pourrait réaliser des économies de plus d'un million de dollars.

L'exactitude de la mesure en continu de la teneur en humidité des résidus de bois est extrêmement importante pour le fonctionnement efficace d'une chaudière dans l'industrie des pâtes et papiers. Les résidus de bois sont généralement acheminés à la chaudière par un convoyeur à courroie; la teneur en humidité doit donc être mesurée rapidement, afin de bien régler le fourneau. L'utilisation de combustibles fossiles supplémentaires compense l'augmentation de la teneur en humidité des résidus de bois. Un mauvais contrôle de la chaudière entraîne une combustion inefficace et des fumées inacceptables.

Relativement au deuxième objectif, un détecteur d'humidité a été construit au laboratoire de l'Ouest de la société Forintek Canada, afin de mesurer la teneur en humidité des résidus de bois. Ce détecteur contenait un radiateur de 2 200 watts pour chauffer les résidus de bois et deux détecteurs de chaleur telatemp 44-1MAR à infrarouge actionnés par deux cellules photo-électriques pour mesurer l'augmentation de la température. Des mesures de la teneur en humidité effectuées sur des résidus de bois, provenant de la côte et de l'intérieur de la Colombie-Britannique, ont révélé des fluctuations considérables de la

teneur en humidité d'un jour à un autre. Ces données montrent l'importance de pouvoir contrôler l'ajout des combustibles fossiles acheminés à la chaudière, dans une usine de pâtes et papiers, en mesurant rapidement et avec exactitude la teneur en humidité des résidus de bois. L'utilisation du nouveau détecteur d'humidité Forintek, afin de contrôler l'addition du combustibles de soute acheminé à la chaudière, permettra à l'usine de pâtes et papiers Harmac de McMillan Bloedel d'économiser environ un million de dollars par année.

Les résultats du présent rapport montrent que le détecteur d'humidité Forintek possède un excellent potentiel pour la mesure rapide et en continu de la teneur en humidité du bois non séché et des résidus de bois et qu'il peut être efficace pour la régulation de procédé. On recommande que le nouveau détecteur d'humidité soit mis à l'essai dans une usine de pâtes et papiers pour contrôler la chaudière en mesurant la teneur en humidité des résidus de bois et en contrôlant l'addition de combustibles fossiles.

1. INTRODUCTION

The determination of moisture content of unseasoned lumber, hog-fuel and other wood products for various uses cannot be overemphasized. Moisture content control in processing requires a rapid and reliable means of moisture determination.

Various methods including electrical (Brady, 1964; Considine, 1974; Dennis and Beall, 1977), microwave (Balls and Boersma, 1973; Busker, 1968) and nuclear radiation (Loos, 1965; Richesson *et al.*, 1967) have been used to measure moisture content (MC) in unseasoned wood materials. In general, however, these methods are limited, since they require a knowledge of the bulk density of the material. In addition, the accuracy is seriously affected by variation in sample temperature and species. In the case of the nuclear radiation method, the equipment is very expensive and personnel must be adequately protected from the radiation source. A method using an infrared reflection technique (Beuther, 1965) has the advantage that it does not require knowledge of the bulk density of the material. Its accuracy, however, is affected by changes in the material's surface characteristics, such as different species and particle size.

Forintek Canada Corp. has developed a new novel method (Clarke and Troughton, 1985, 1986) to measure the MC of unseasoned wood materials. Laboratory testing of this new moisture sensor under an Energy, Mines and Resources contract (Troughton and Warren, 1985) showed very good correlations between actual MC and temperature rise for different types of hog fuel material.

An accurate method to measure MC in unseasoned lumber is needed to properly sort the lumber into MC ranges and allow them to be dried efficiently. Less overdry, degrade and energy waste will result when the lumber is sorted effectively. Furthermore, increased production rates can be achieved since the lumber containing less moisture can be run through the dry kiln at increased rates of speed.

The recovery boiler is the largest energy source in the typical pulp and paper kraft mill. It generally accounts for about 40 percent of the kraft mill's total energy requirement. In B.C. pulp and paper companies, they indicate that biomass (hog fuel) is a very important fuel source. Specifically, fossil fuel has been greatly displaced during the period 1974 to 1984 (Robinson and Wetton, 1986). Biomass consumption increased by over 36 percent during this period, displacing fossil fuel, and is expected to

continue to play an important role in the future. This increase in biomass consumption resulted in an annual fossil fuel saving equivalent to 3.5 million barrels of oil in the B.C. pulp and paper industry. There is a very large potential (Helliwell and Cox, 1978) for the economic use of hog fuel to replace fossil fuels and to generate electricity in the B.C. pulp and paper industry.

The new Forintek method holds considerable promise in measuring the MC of hog fuel being fed to a recovery boiler and could be used to control the burning of hog fuel with fossil fuel in the boiler. Thus, the rapid and accurate measurement of MC of the hog fuel would result in better control of the boiler operation.

The present study evaluated the moisture sensor from two perspectives: a) designing, building and evaluating the new plant prototype for sorting lumber on a commercial scale and determining the economic benefits to the forest products industry, and b) designing, building and evaluating a laboratory model for measuring the moisture content of hog fuel to ascertain the weekly and monthly change for its use in boilers.

This report deals with the study in two parts, A and B.

2. OBJECTIVES

a) To design, build and evaluate a new plant prototype moisture sensor for sorting unseasoned lumber on a commercial scale and determining the economic benefits to the forest products industry.

b) To design, build and evaluate a laboratory model moisture sensor for measuring MC in hog fuel to determine the weekly and monthly change for use in boiler operation in pulp and paper plants.

PART A - LUMBER

3. EXPERIMENTAL

3.1 Method

A moisture measuring system was constructed at Forintek Canada Corp. and transported to the mill site (Weldwood of Canada, Williams Lake). Figure 1 shows how the apparatus was mounted over the green chain. Two 5,000 watt infrared heaters parallel to each other and 24 inches apart were attached to the four-ft. by eight-ft. aluminum metal frame. Three infrared heat sensors and three photocells were also attached to the frame. Sensors 1, 2 and 3 were Telatemps Infrared 44-1MAR models. The Telatemps Infrared 44-1MAR models were directly aligned 15 inches in front of the heaters, using adjustable clamps. Sensor 1 measured the initial temperature. The moisture sensor was set up on the green chain near the J-bar. The speed of the conveyor belt was 90 ft./min. The Forintek moisture sensor was interfaced through an IBM-PC to the sorting computer in order to perform the following functions:

a) To calculate the dMax and to signal whether the lumber was above or below 35 percent moisture content (MC).
b) To sort the samples into their respective bins.
c) To mark the samples with ink when they were above 35 percent MC.
d) To link up with the Weldwood computer to give the size and quantity of lumber measured under the sensor.

Two trials were conducted at the plant. The preliminary plant trials were conducted on November 13 and 14, 1986, at Williams Lake, where 911 pieces of 16-ft., 2 x 6, unseasoned spruce-pine-fir (SPF) lumber were graded and sorted into a dry and wet sorts, using the Forintek moisture sensor. A control and one wet and three dry sorts, each containing over 200 pieces of graded lumber, were dried in the Weldwood dry kiln for the following times; 29 hours for the control, one dry and the wet sort; 24 hours for the second dry sort and 19 hours for the third dry sort. For these dry kiln schedules, the dry and wet bulb temperatures were set at 210°F and 170°F,

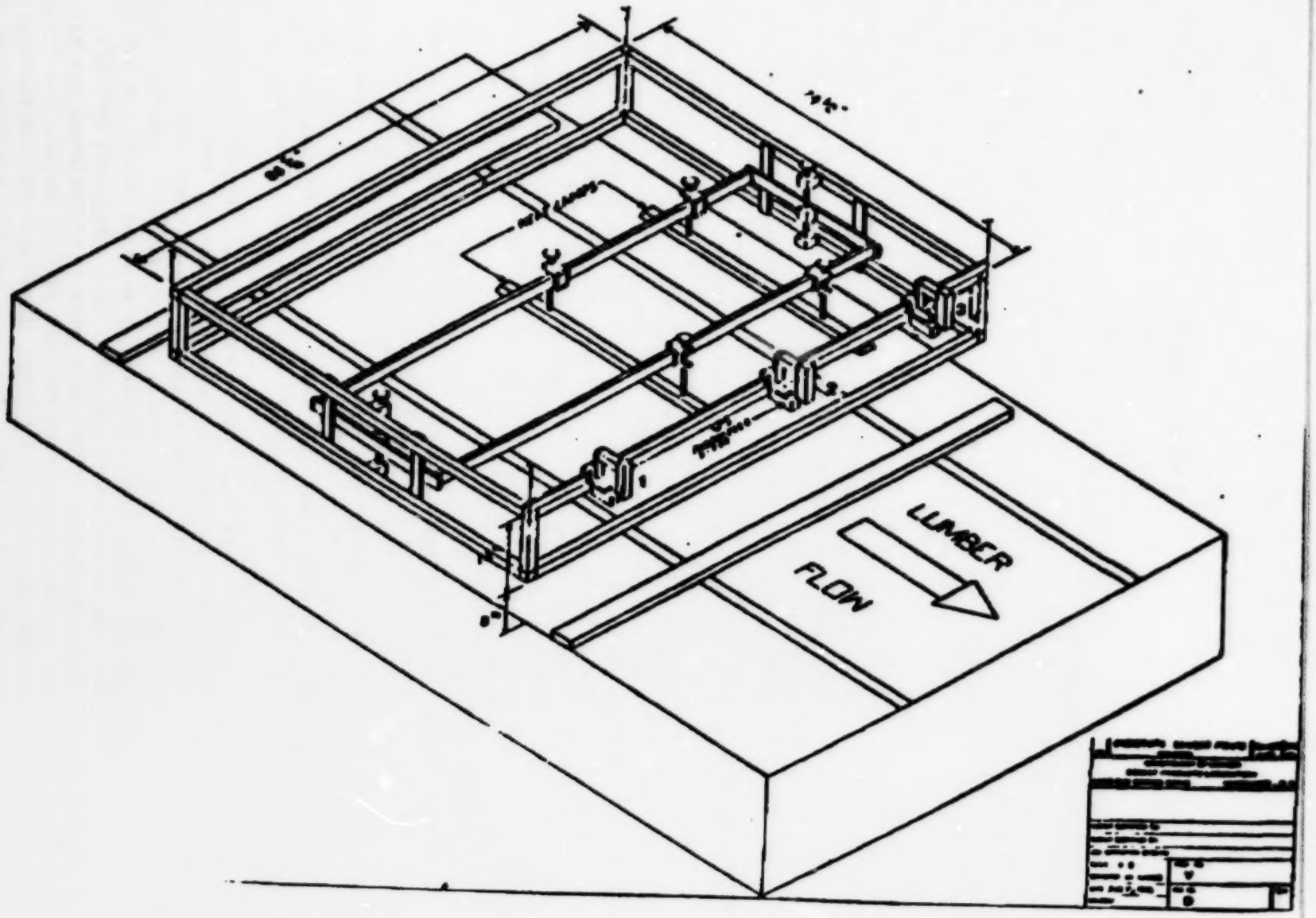

Figure 1. Lumber Moisture Sensor on Green Chain

respectively. After drying, the lumber was evaluated by Weldwood and Forintek personnel for moisture content and grade downfall. The plant was able to establish the following:

a) the economics of the Forintek moisture sensor in sorting lumber for their operation, and;
b) whether the study should progress further to warrant a large commercial trial.

The results of the preliminary trial based on economics were sufficiently promising to warrant a large-scale commercial trial. A statistical sampling was made to determine the moisture ranges indicated by the dMax (Figures 2 and 3) before the commercial run was started.

For the commercial run, three kiln charges of random lengths consisting mainly of 2 x 4 and 2 x 6 SPF were sorted. Each kiln charge contained approximately 170,000 bd.ft. of lumber. In order to assess the grade outturn and recovery, the following groupings were made:

1. Group A (Control). None of the samples were measured under the sensor. A full kiln charge consisting of samples above and below 35 percent MC was dried with a preset schedule of 210°F dry bulb (DB) and 170°F wet bulb (WB) for 32 hours.

2. Group B (Wet Sort). This group consisted of samples above 35 percent MC and was subjected to the same kiln schedule as the control, and dried for 33 hours.

3. Group C (Dry Sort). This group consisted of samples below 35 percent MC and was subjected to the same kiln schedule of 210°F DB and 170°F WB and dried for 20 hours.

The kiln schedules are shown in Table 1. The kiln charges were dried to the preset schedule (approximately five percent of the pieces were metered with a resistance moisture meter to determine whether the charges were ready to be taken out of the kiln). The kiln charges were then planed. Each specimen was graded to determine recovery and grade outturn.

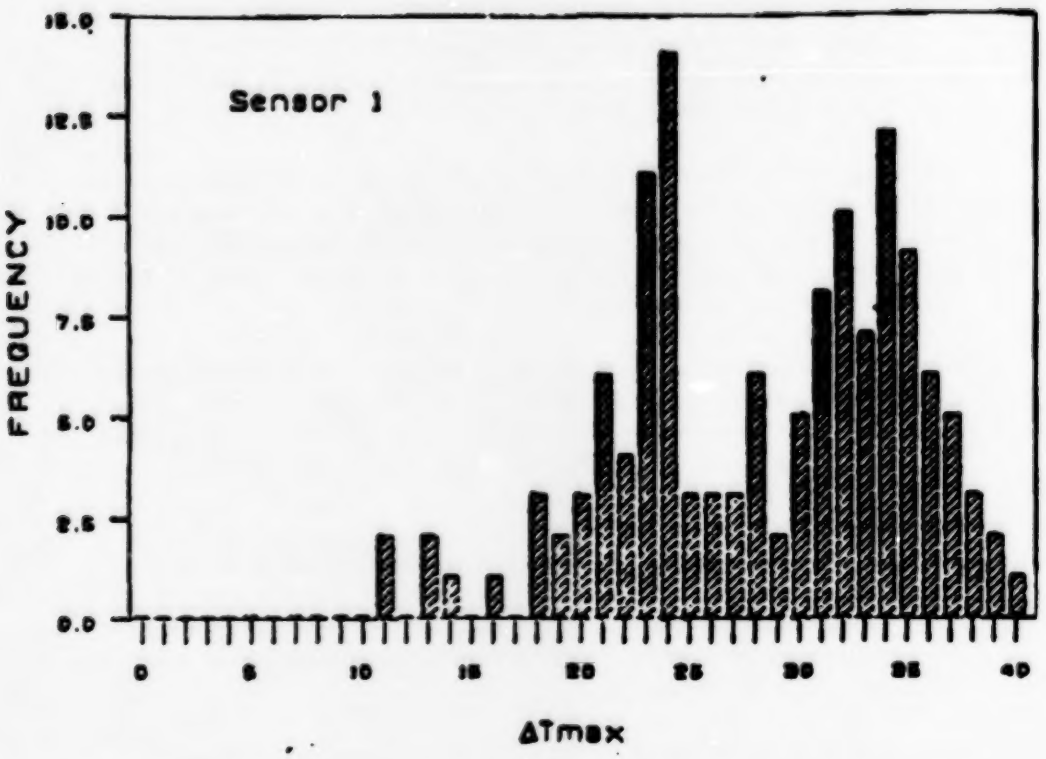

Figure 2: Frequency Graph of Temperature Readings

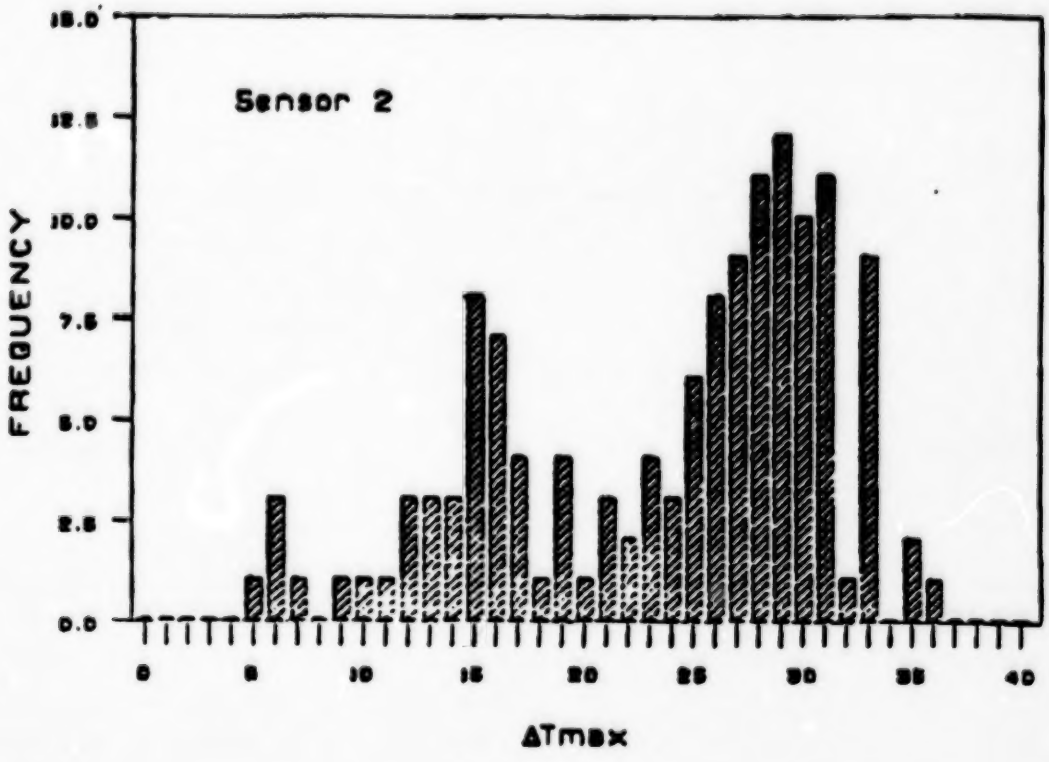

Figure 3: Frequency Graph of Temperature Readings

Table 1

Kiln Schedules and Preset Time for Three Commercial Charges

Treatments	Kiln	Schedule	Preset Time (not computer controlled)	
Dry Charge (under 35% MC)	DB	210°F	20 hours	2x4 and 2x6 random lengths
	WB	170°F		
Wet Charge (over 35% MC)	DB	210°F	33 hours	2x4 and 2x6 random lengths
	WB	170°F		
Control (over and under 35% MC)	DB	210°F	32 hours	2x4 and 2x6 random lengths
	WB	170°F		

4. RESULTS AND DISCUSSION OF PART A

The results of the small trial of November 15 and 16 showed that, after drying, the wet sort had the highest percentage of wet lumber pieces over 30 percent MC, 6.7 percent, followed by the control, 2.5 percent, and the dry sorts which ranged from zero to 1.4 percent. The control showed the greatest downfall due to drying and trim loss, 3.61 percent; the wet showed the least with 0.32 percent; and the three dry sorts of 19, 24 and 29 hours were 0.65, 1.00 and 1.15, respectively.

4.1 Grade Outturn and Recovery

For the large commercial trial, the grade outturn and recovery were calculated by Weldwood and Forintek staff.

The prices per 1,000 bd.ft. (Table 2) are from the "Random Length" publication of March 13, 1987, when the mill trial was conducted. The economical benefits per 1,000 bd.ft. of the wet and dry sorts over the control based on grade outturn and recovery was $8.5/1,000 bd.ft. The calculations used to arrive at this number are shown in Tables 3 and 4. The percentage improvement of sorting over the control was 5.9 percent. The increase in percent recovery of the wet and dry sorts over the control was 3.45 percent. These results are significant since for a plant producing 100 million bd.ft. per year the savings are over 1 million dollars.

4.2 Energy Savings and Reduction in Kiln Drying Time

It was difficult to calculate the energy savings due to reduction in kiln drying since the cost varies from season to season. Calculations in savings must be based on whether the plant production is large and does not have enough kiln drying capacity. Results show that the dry kiln charge (under 35 percent MC) dried in 20 hours, whereas the wet charge and the control took 33 hours. The reduction of kiln drying time as

Table 2

Prices Obtained From Random Length Publications of March 13, 1987
and Values of Product Based on Grade Outturn by Percent

Treatments		Price ($) per 1,000 bd.ft.	Average Price (2x4 and 2x6)
Dry Charge (under 35% MC)	2x4	200.52	186.86
	2x6	173.21	
Wet Charge (over 35% MC)	2x4	199.34	185.18
	2x6	171.03	
Control (over and under 35% MC)	2x4	198.80	183.81
	2x6	168.82	

Table 3

Grade Outturn and Recovery for Three Commercial Kiln Charges

Treatments		Bd.ft. Into Kiln & Planer	Bd.ft. Out of Planer	Recovery Percent	2 and Better Percent	Utility Percent	Economy Percent
Dry Kiln Charge	2x4	83,719	74,175	88.6	91.5	6.8	1.3
(under 35% MC)	2x6	99,198	95,825	96.6	89.5	9.5	0.9
	TOTAL	182,917	170,000	92.2			
Wet Kiln Charge	2x4	95,934	86,042	89.7	90.5	7.0	1.7
(over 35% MC)	2x6	70,438	63,183	89.7	87.4	11.1	1.3
	TOTAL	166,372	149,225	89.7			
	Average Recovery of Wet and Dry Sort = 91.2						
Control Kiln Charge	2x4	89,664	78,366	87.4	89.6	8.2	1.4
(over and under 35% MC)	2x6	87,138	76,769	88.1	85.4	12.2	
	TOTAL	176,802	155,135	87.75			

NOTE: Percent downfall of wet and dry sort over control = 3.45.

Table 4

Economic Calculations of Grade Outturn and Recovery of Three Commercial Kiln Charges

Treatments		Bd.ft. (Planer)	Price/1,000 ($)	Total ($)	Price per 1,000,000 bd.ft.	Percent Recovery	Recovery (for 1,000,000 bd.ft.)
Dry Kiln Charge	2x4	74,175	200.52	14,873.6		92.6	
(under 35% MC)	2x6	95,825	173.21	16,597.8			
	TOTAL	170,000		31,476.4			
Wet Kiln Charge	2x4	86,042	199.34	17,151.6		89.7	
(over 35% MC)	2x6	63,183	171.03	10,806.2			
	TOTAL	149,225		27,957.8			
Combined Wet and Dry		319,225		59,434.2	186,182.1	91.2	169,799
Control Kiln Charge	2x4	78,366	198.80	15,579.2			
(over and under	2x6	76,769	168.82	12,960.1			
35% MC)							
	TOTAL	155,135		28,539.3	183,964.2	87.7	161,336.6

Benefits per 1,000 bd.ft. of wet and dry sort over control:

Combined wet and dry charge grade outturn and recovery values	$ 169,799.0	
	$ 161,336.8	
Difference	8,462.2	$8.5 per 1,000 bd.ft.

NOTE: Average value calculated for Random Length Publication.

observed from this commercial run is approximately 22 percent, but again this will vary with individual kilns.

4.3 Moisture Content

The moisture content for the dry load and the wet load was slightly higher than average but was within the acceptable standard. The surrounding temperature was higher when the control was placed in the kiln and the set kiln temperature was achieved in a shorter time than the wet and dry charges. Plant personnel found that there was no planer downtime, and lumber breakage due to overdrying was eliminated. This was the best result the plant had achieved over a long period of time.

Based on the grade outturn and recovery, the savings on 100,000,000 bd.ft. per year is over 1 million dollars. Factors such as energy costs were not taken into account in this commercial mill trial.

PART B - HOG FUEL

5. TEST LOCATIONS AND DESCRIPTION

Two test sites were undertaken. Site A was located in the interior of the province at Weldwood of Canada (Williams Lake). Site B was located at the Coast MacMillan Bloedel (New Westminster). No attempt was made at Site A to separate the hog fuel by particle sizes. The residue consisted of a beetle-killed SPF mixture of shavings, sawdust and bark. Samples were bagged on a daily basis for one month (March) and sent to Forintek's Western Laboratory for moisture content analysis both with the new moisture sensor and the oven-dry method.

At Site B the residue was a mixture of red and yellow cedar and was divided into three categories containing different particle sizes.

1) Bark: defined as material which went through the hogger as the logs were being peeled. Material from two species were mixed (red and yellow cedar).

2) Planer shavings: material which came from inside the mill.

3) Sawdust particles: particles which would generally go through a half-inch sieve.

Figure 4 shows the location sites where the bark and planer shavings were collected. Figure 5 shows where the sawdust particles were collected in relationship to the bark and planer shavings. Sampling at Site B was done for the months of June and August, 1987. Specimens from the three groups were collected on a daily basis for the months of June and August and measurements were made with the moisture sensor and the oven-dry method.

5.1 Method

A moisture measuring system was constructed at Forintek Canada Corp. for measuring hog fuel. Figure 6 shows how the apparatus was constructed and set up on the veneer line. One 2200 watt infrared heater was attached to the metal frame.

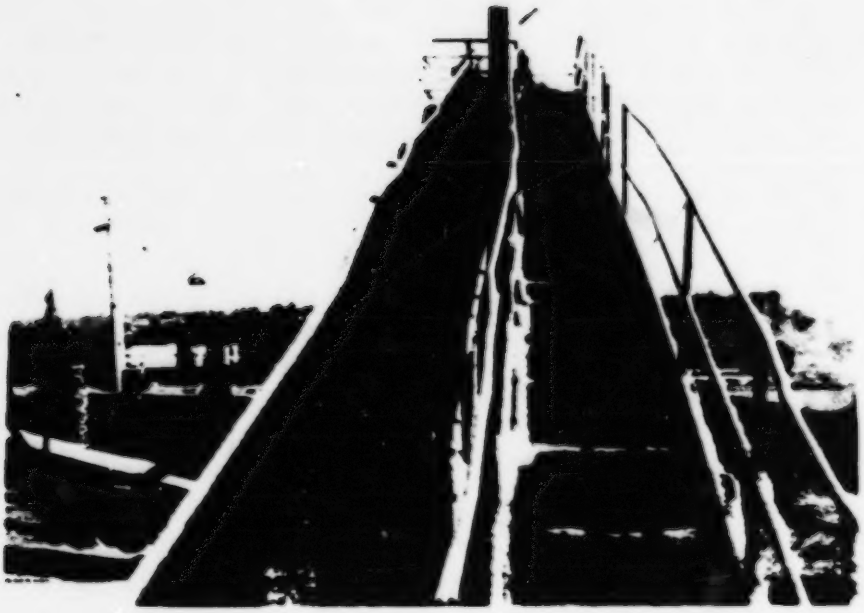

Figure 4. Bark and Planer Particles Collection Site

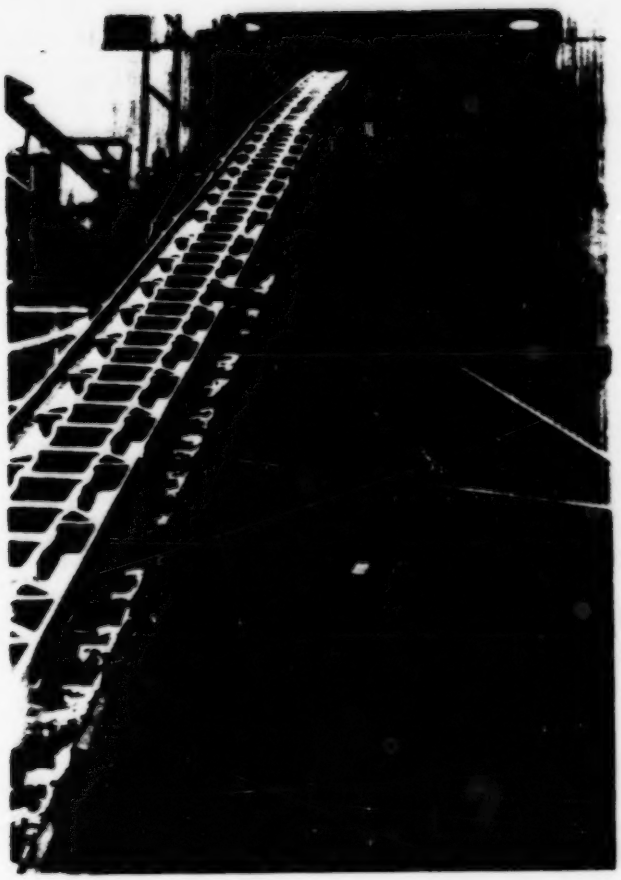

Figure 5. Sawdust Collection Site

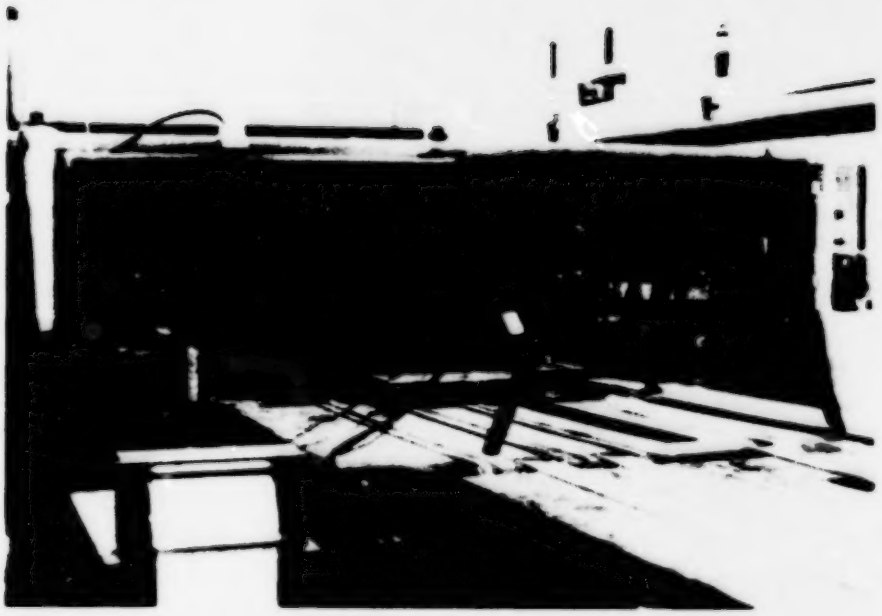

Figure 6. Hog Fuel Moisture Measuring System

Two infrared heat sensors and two photocells were also attached to the frame as shown in Figure 7. Sensors 1 and 2 (Figure 7) were Telatemp Infrared 44-1MAR models. One Telatemp Infrared 44-1MAR was directly aligned 15 inches in front of the heaters using adjustable clamps and the other sensor was used to measure initial temperature.

This moisture measuring system was mounted on a frame over the laboratory's veneer green chain. The infrared heaters were one inch above the surface of the hog fuel. One box was constructed from quarter-inch plywood with outside dimensions of one by five feet and a depth of one inch. Two compartments were positioned in the box to pass under an infrared sensor as shown in Figure 7.

A sample of either hog fuel, shavings or sawdust was packed level in each compartment and run underneath the sensor at 22.5 ft./min. on a conveyor belt system. After the run, samples of approximately 150 grams were placed in beakers and weighed immediately, then oven-dried at 105°C until constant weight was reached. The moisture content was then calculated on a green weight basis.

6. RESULTS AND DISCUSSION

6.1 Moisture Content Data and Economics

Figures 8 to 14 indicate the temperature changes measured by the Forintek moisture sensor. The daily differences were graphed and the results show that there is an urgent need for pulp mills which use bunker fuel to supplement their mill residue. The quantity of bunker fuel must be controlled to fit the daily moisture content differences.

Tables 5 and 6 show an analysis of the oven-dry moisture contents of the residue collected in the interior as well as the coast of British Columbia. The material collected at Weldwood of Canada (Williams Lake) was obtained from beetle-killed SPF logs. This meant that the moisture content was lower than that for logs which have not been attacked. The average moisture content for the month of March was 29.7 percent. Figure 8 shows the day-to-day fluctuation of the moisture contents. This plant did not separate their mill

Table 5

Weldwood Hog Fuel Moisture Content
(March)

Day	Hog Fuel Moisture Content (%)
1	
2	30.8
3	26.4
4	
5	25.5
6	36.1
7	
8	
9	26.9
10	27.6
11	25.0
12	37.9
13	32.5
14	
15	
16	25.9
17	31.3
18	31.1
19	30.7
20	32.5
21	
22	
23	31.3
24	31.5
25	26.9
26	29.2
27	26.8
AVERAGE	29.7

Table 6

MacMillan Bloedel Hog Fuel Moisture Content

Day	Sawdust (%)		Planer Shavings (%)		Bark (%)	
	June	August	June	August	June	August
1						
2						
3	41		44.9		59.0	
4	42.1		37.2		55.7	
5	55.8		30.2		61.1	
6						
7						
8						
9	41.5		32.7		63.3	
10		46.7				54.0
11	49.9		42.3		64.1	
12		46.3		22.6		60.4
13		44.7		34.1		60.7
14		51.2		35.9		66.8
15	46.3		39.6		60.4	
16						
17	52.4	63.8	49.8	28.0	69.2	61.4
18		45.3		38.6		62.6
19		46.3		39.1		62.6
20		58.7		32.7		60.3
21						
22						
23	47.8	63.1	13.0		61.1	
24				39.2		57.9
25	50.6		28.1		52.5	
26						
27						
28						
29						
30						
31						
AVERAGE	47.5	51.8	35.3	33.7	60.7	60.7

residue into particle sizes since most of it was sold to the surrounding plants to supplement their energy requirements.

The MacMillan Bloedel plant located on the coast separated some of their mill residue. Some material such as sawdust was used in their own boilers, and the wood chips and shavings were sent to Vancouver Island for their pulping needs. Table 6 gives the moisture contents of the different particle size studied for the months of June and August. The average moisture contents for the month of June were 60.7 percent for bark, 47.5 percent for sawdust and 35.3 percent for planer shavings. For the month of August, average moisture contents were 60.7 percent for bark, 51.8 percent for sawdust and 33.7 percent for planer shavings. Figures 9 to 14 indicate the daily trends in the variation of moisture contents and show a very large fluctuation. For example, in June the MC of the planer shavings varied from 13.0 to 49.8 percent.

This study shows that the moisture content of the residue has a great effect on the economics for boiler operation. The new moisture sensor gives a quick and efficient method to monitor the moisture content on line so that plants which supplement their mill residue with bunker fuel can use this information for controlling their fossil fuel. For example, if the residue has a high moisture content then a large quantity of fossil fuel is required and vice versa.

The modification necessary to the plant will be very small. The sensor will be installed and the signal will be transmitted to the plant's computer for controlling the quantity of fuel required.

By installing the new Forintek moisture sensor to control the addition of bunker fuel to the boiler, the savings calculated for the MacMillan Bloedel Harmac plant are estimated to be one million dollars annually. This technology could easily be transferred to other pulp mills which utilize large quantities of wood waste for their energy consumption.

MOISTURE SENSOR, HOGFUEL

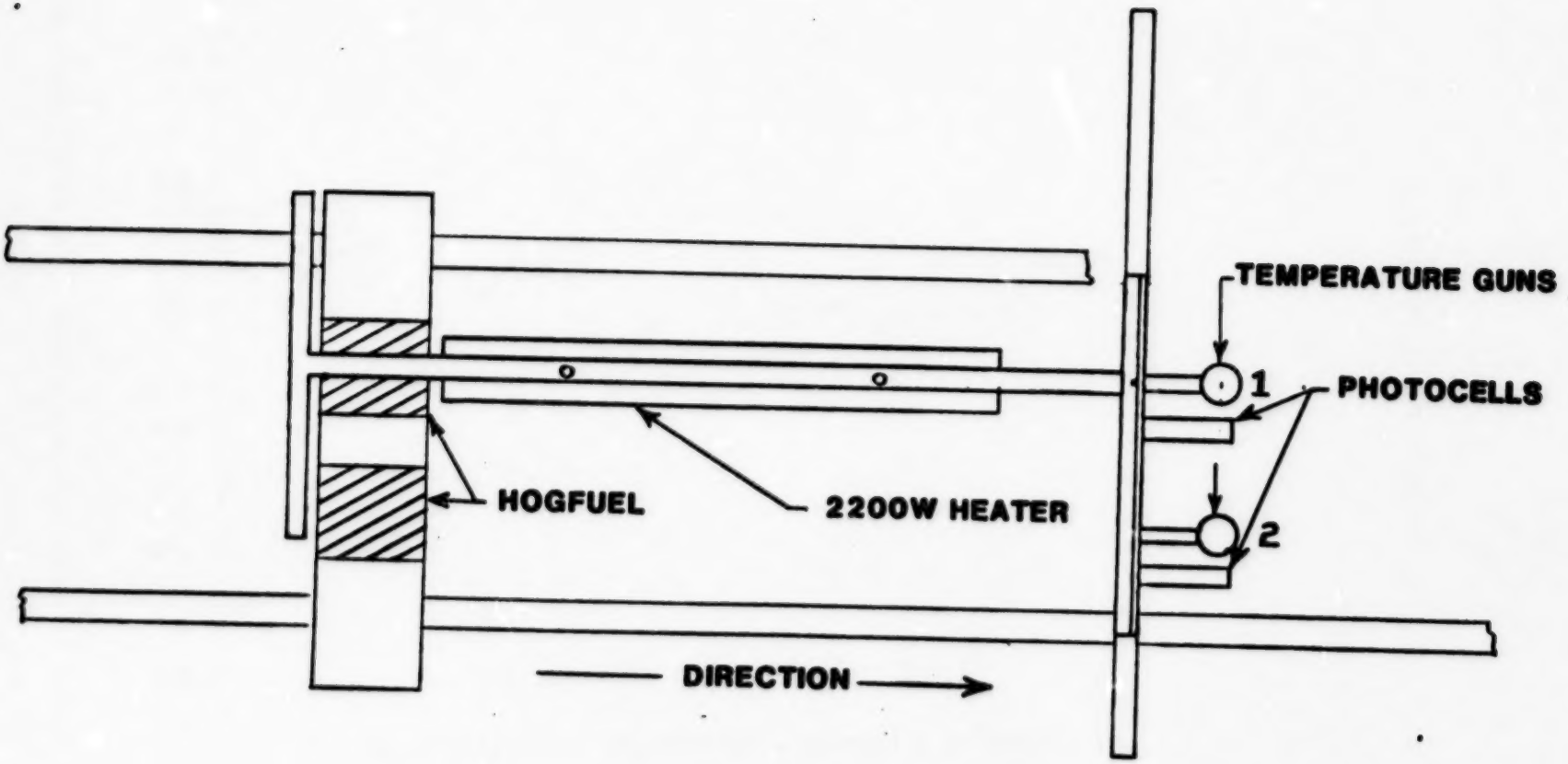

Figure 7: Moisture Sensor, Hog Fuel

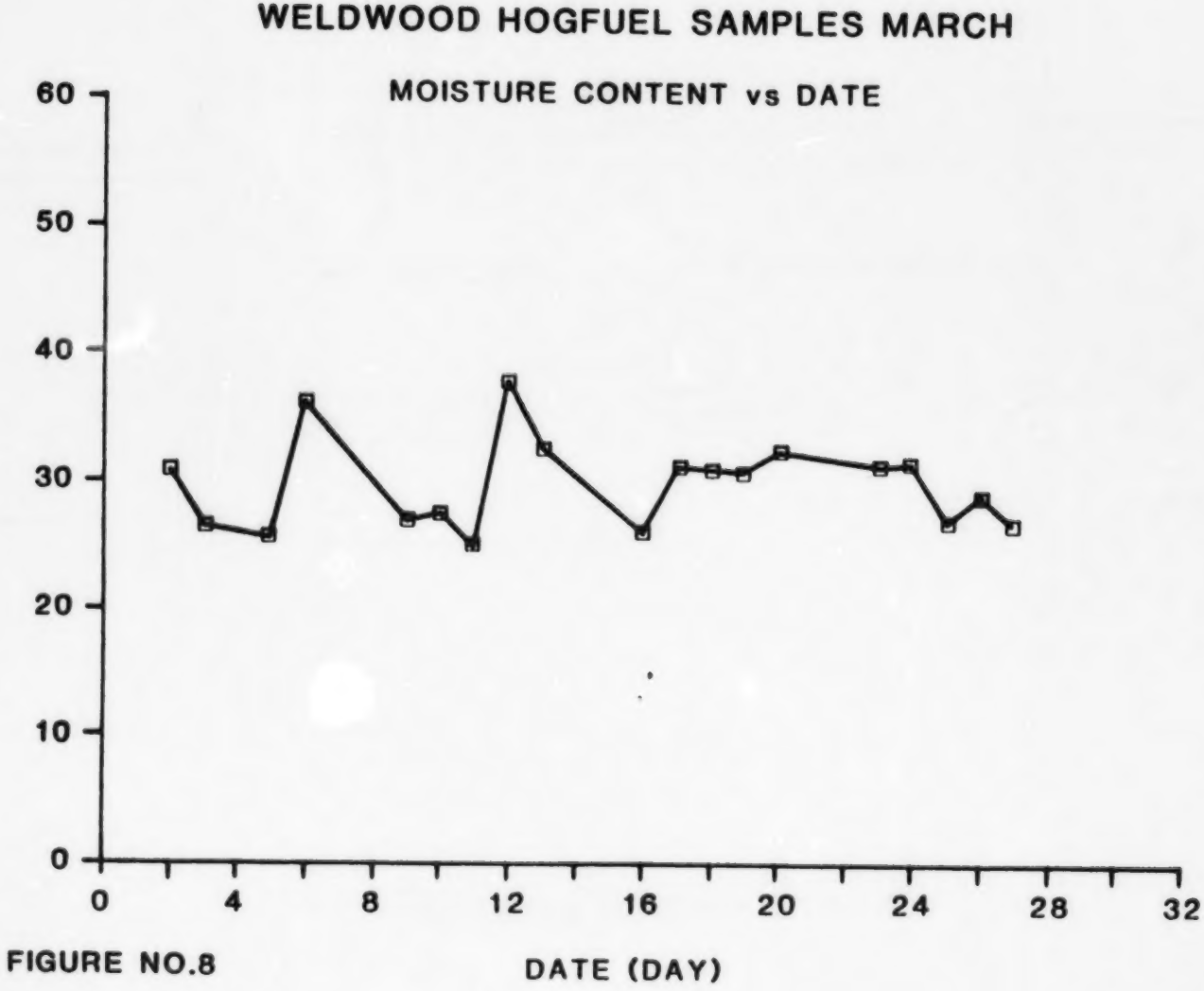

FIGURE NO.8

Figure 8: Daily Temperature Changes for March, June and August

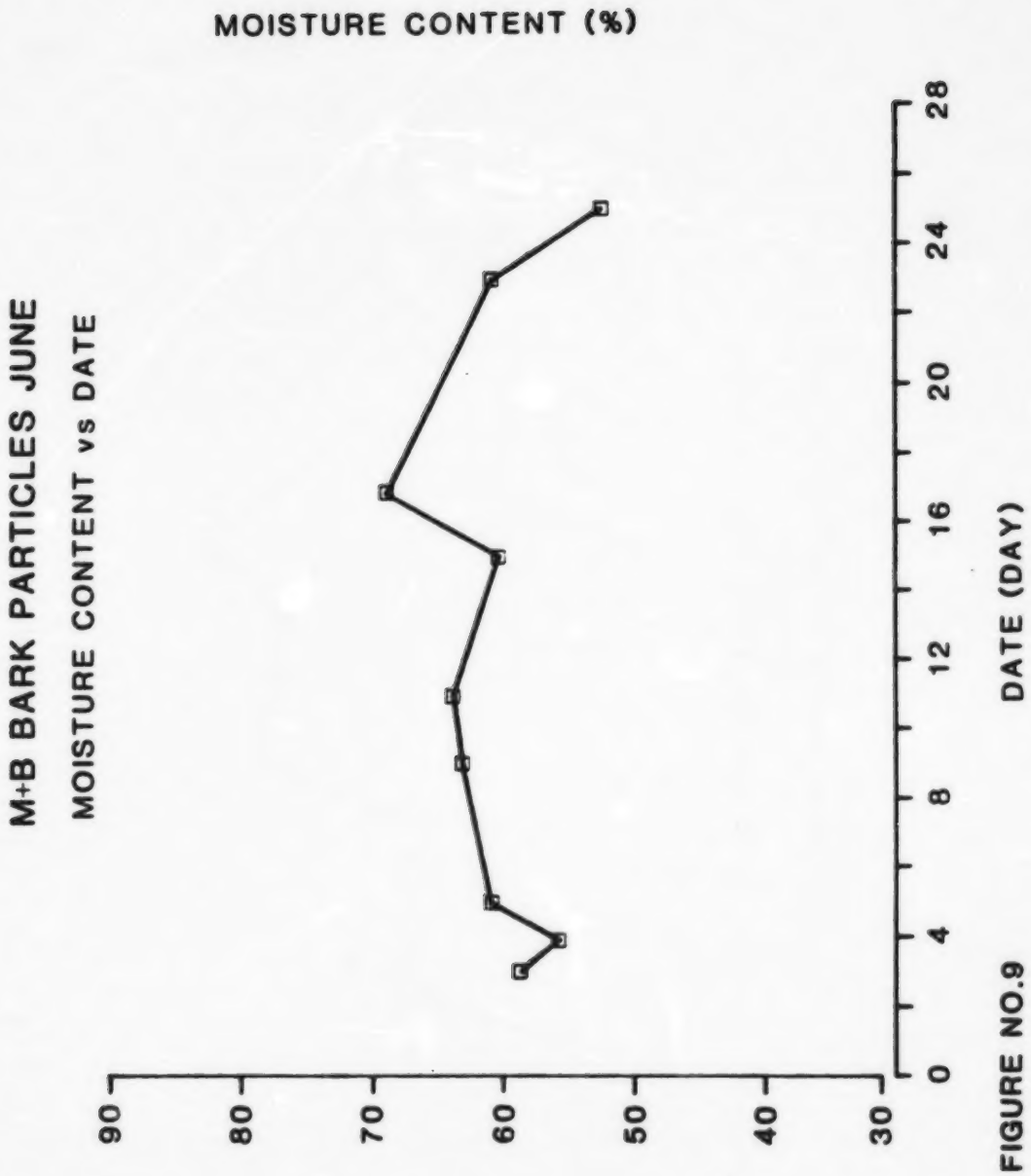

Figure 9: Daily Temperature Changes for March, June and August

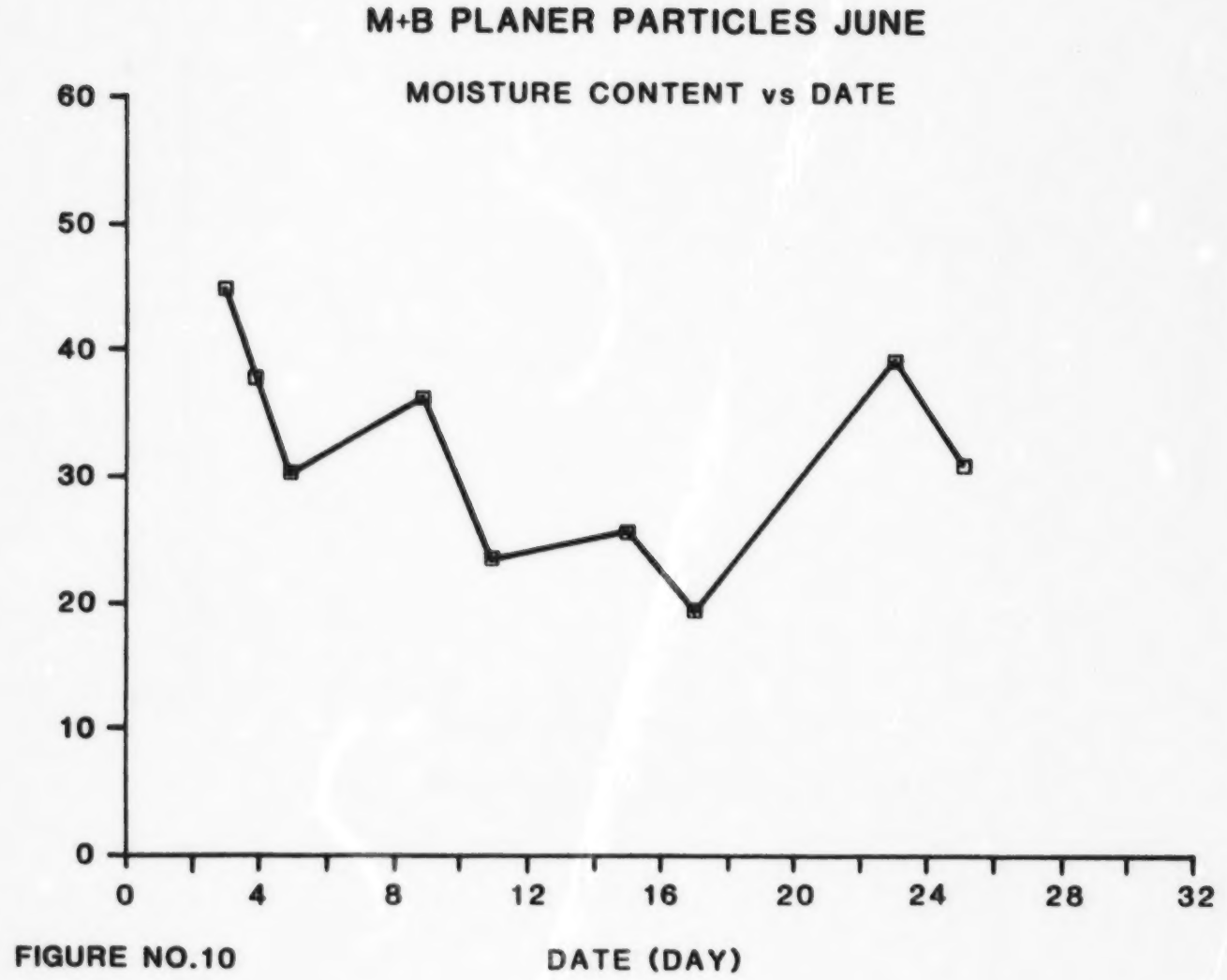

FIGURE NO.10

Figure 10: Daily Temperature Changes for March, June and August

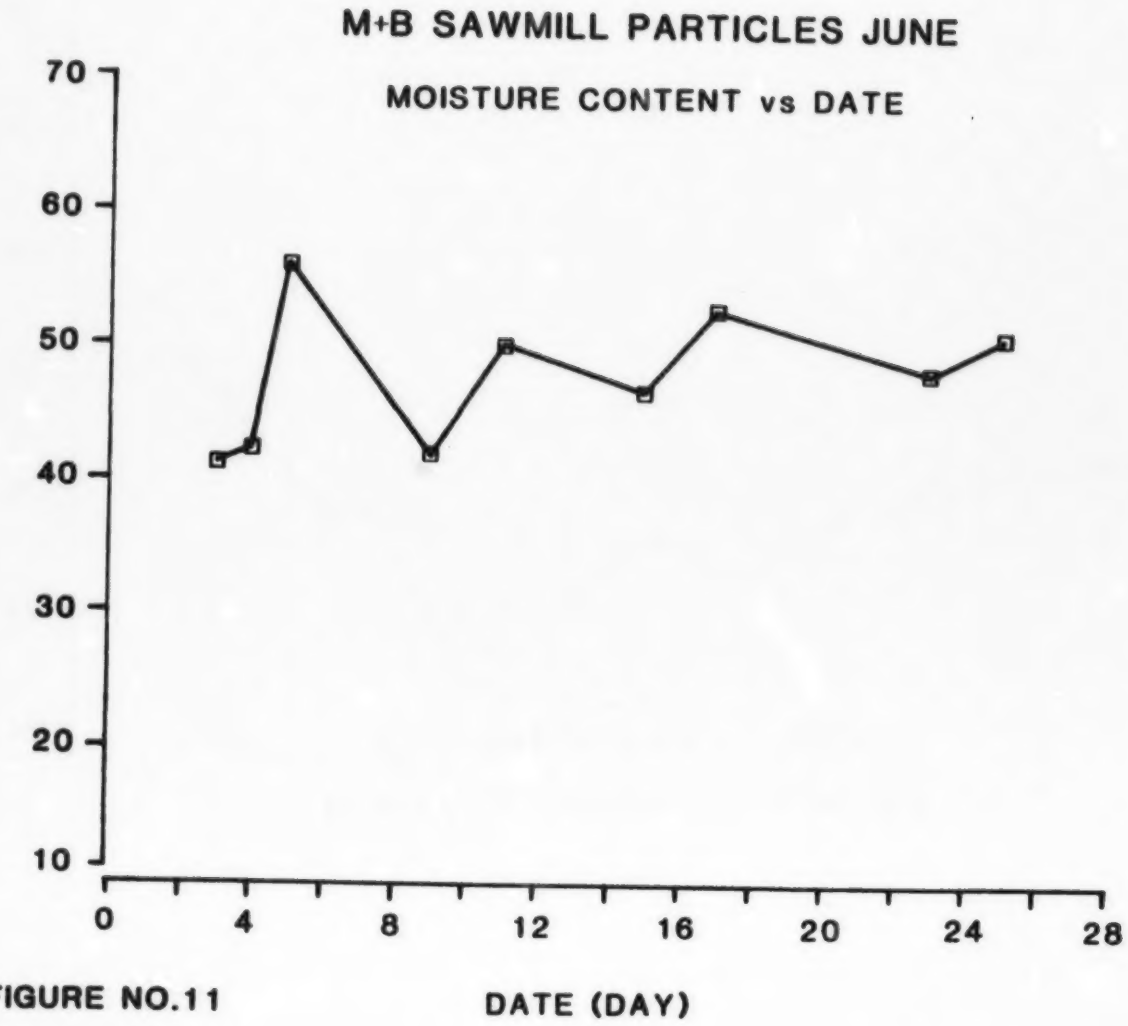

FIGURE NO.11

Figure 11: Daily Temperature Changes for March, June and August

Figure 12: Daily Temperature Changes for March, June and August

Figure 13: Daily Temperature Changes for March, June and August

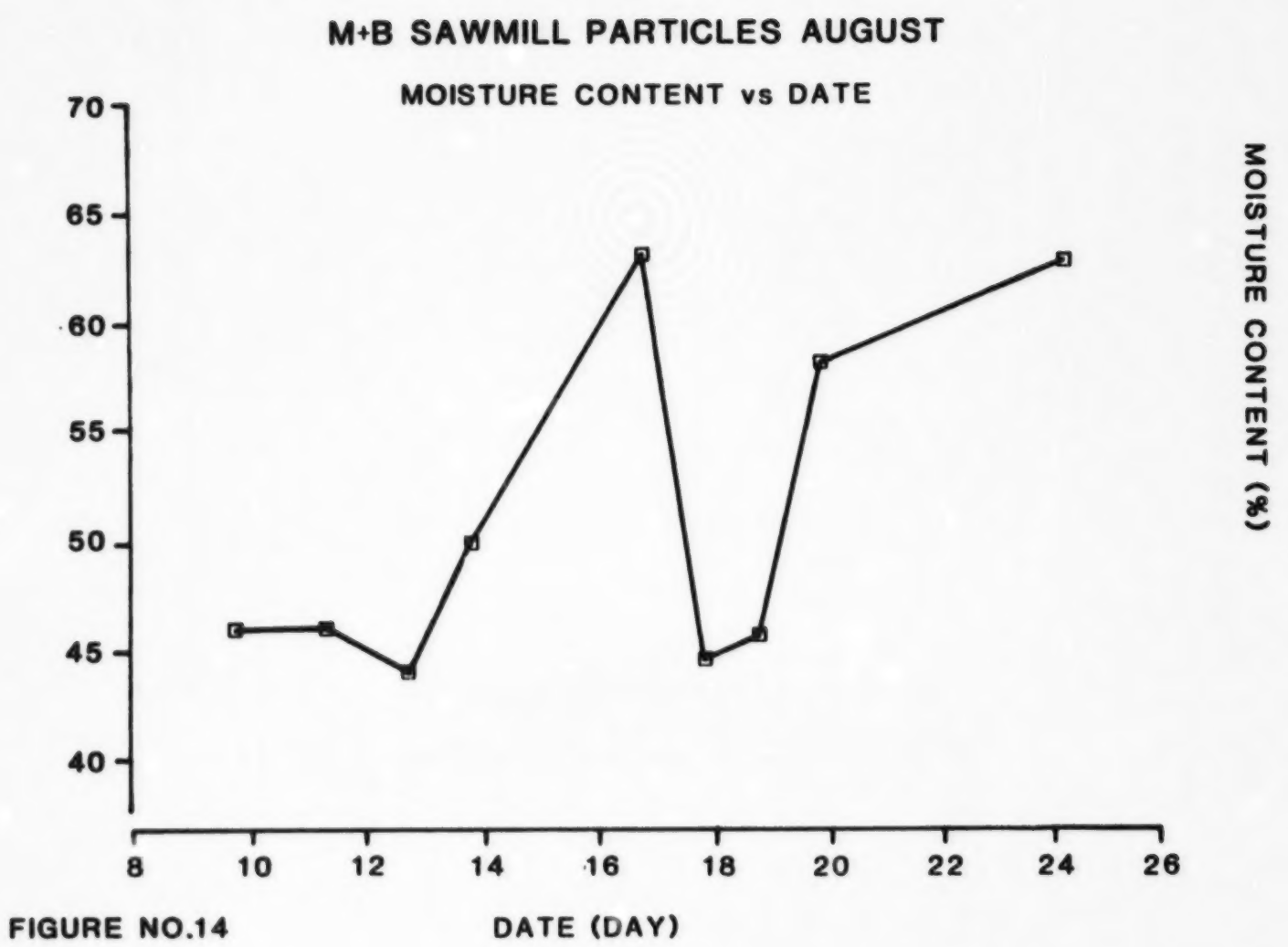

FIGURE NO.14

Figure 14: Daily Temperature Changes for March, June and August

7. CONCLUSIONS AND RECOMMENDATIONS

The results obtained can be summarized in two parts: a) lumber, and; b) hog fuel. The savings based on grade outturn and recovery on 100,000,000 bd.ft. of lumber per year is over one million dollars. Factors such as energy cost were not taken into account in the commercial trial because the energy needs of the plant vary from season to season. The daily, weekly and monthly fluctuations of the hog fuel indicated that fossil fuel mixed with the hog fuel could be controlled by utilizing the results of the moisture contents.

It is recommended that a plant prototype be designed, built and tested on the Harmac plant pulp mill for policing the quantity of bunker fuel consumed by the plant. This could result in a saving of over one million dollars annually.

8. REFERENCES

Balls, B.W. and J. Boersma. Moisture sensors for papermachine control. Pap. Technol. 1973. 14(6):331.

Beuther, A.J. An infrared-backscatter moisture gauge. Tappi 1965. 48(a):490.

Brady, E.R. Moisture measurement on flowing wood chips. Tappi 1964. 47(6):173A.

Busker, L.H. Measurement of water content above 30% by microwave methods. Tappi 1968. 51(8):348.

Clarke, M.R. and G.E. Troughton. 1985. Method and Apparatus for Rapidly Determining the Moisture Content of a Substance. Canadian Patent 1,189,192.

Clarke, M.R. and G.E. Troughton. 1986. Method and Apparauts for Rapidly Determining the Moisture Content of a Substance. United States Patent 4,612,802.

Considine, D.M. (ed.) Process Instruments and Controls Handbook. McGraw Hill, Second Edition. 1974.

Dennis, J.R. and F.C. Beall. Evaluation of a new portable radiofrequency moisture meter on lumber with drying gradients. Forest Prod. J. 1977. 27(8):24.

Helliwell, J.F. and A.J. Cox. Wood Wastes as an Energy Source for the B.C. Pulp and Paper Industry: Economic Implications and Institutional Barriers. Programme in Natural Resource Economics. University of B.C. 1978. Resources Paper No. 19.

Loos, W.E. Determining moisture content and density of wood by nuclear radiation techniques. Forest Prod. J. 1965. 15(3):102.

Richesson, M.A., L.L. Clap and R.L. Miller. Continuous measurement of chip moisture. Tappi 1967. 50(6):81A.

Robinson, G. and C.E. Wetton. The Role of Biomass in the B.C. Pulp and Paper Industry Energy Strategy: 1974-1984. Canadian Forestry Service, Pacific Forestry Centre 1986. BC-X-286.

Troughton, G.E. and S.R. Warren. Evaluation of a New Moisture Measuring Method for Determining On-Line Moisture Content in Biomass Feedstock. Forintek Canada Corp. 1985. Energy, Mines and Resources Report, DSS Contract File No.: 025Q.23216-4-6377.